

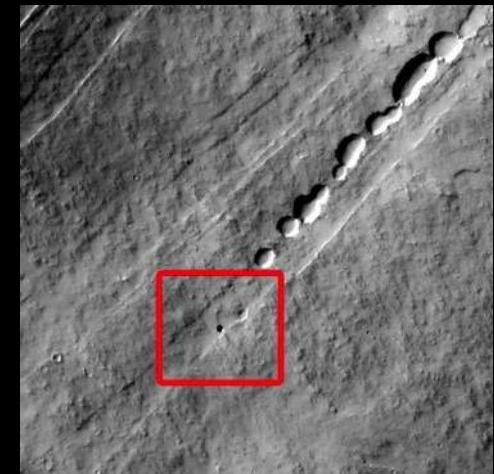


Studies of young Hawai‘ian lava tubes: Implications for planetary habitability and human exploration

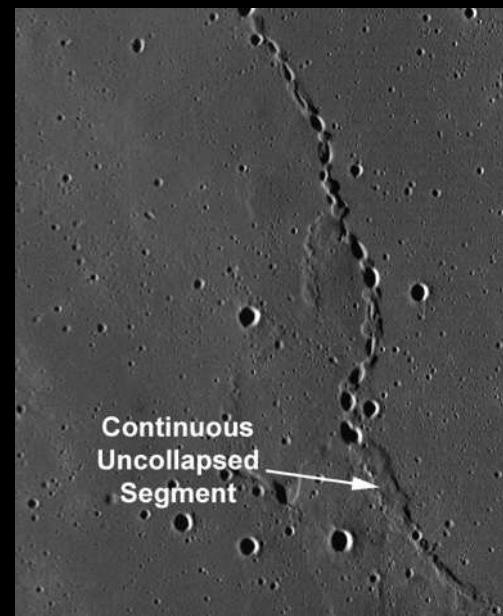
Amy McAdam, Jacob Bleacher, Kelsey Young, Sarah Stewart Johnson,
Debra Needham, Nicholas Schmerr, Brian Shiro, Brent Garry, Patrick
Whelley, Christine Knudson, Slavka Andrejkovicova

Habitability

- Subsurface environments may preserve records of habitability or biosignatures
 - More stable environmental conditions compared to surface (e.g., smaller variations in temperature and humidity)
 - Reduced exposure to radiation
- Lava tubes are expected on Mars, and candidates are observed from orbit
- Few detailed studies of microbial populations in terrestrial lava caves
- Also contain a variety of secondary minerals
- Microbial activity may play a role in mineral formation or be preserved in these minerals
- Minerals can provide insight into fluids (e.g., pH, temperature)



Collapse pit and skylight on Pavonis Mons, Mars



Lunar chain of collapse pits (~50 km long), NW of Gruithuisen crater

Relevance to human exploration

- Science targets
 - Likely sites for geological and astrobiological investigations
 - Careful contamination mitigation strategies needed (biological, chemical)
- Resource targets
 - Potential subsurface volatiles? (e.g., ice)
 - Natural shelters (e.g., from radiation)
 - Understanding any potential hazards to astronaut health
 - Contamination mitigation needed



Lava tubes on Mauna Loa volcano

- Several unique, and Mars-relevant, environmental conditions
 - Very young geologically (~200 years)
 - Intermittent exposure to acid aerosols
 - Degassing at Kīlauea lava lake
 - Adjacent periodic (1880-1940) Mauna Loa lava flow emplacement (< 1 km away)
 - High elevation (~8,000 ft), basalt or volcanic aerosols more likely source of secondary salt ions than ocean
- Located near the Hawai‘i Space Exploration Analog and Simulation (HI-SEAS) Mars analog station
 - Team members serve as science support
 - HI-SEAS team explores tubes for use as safe havens



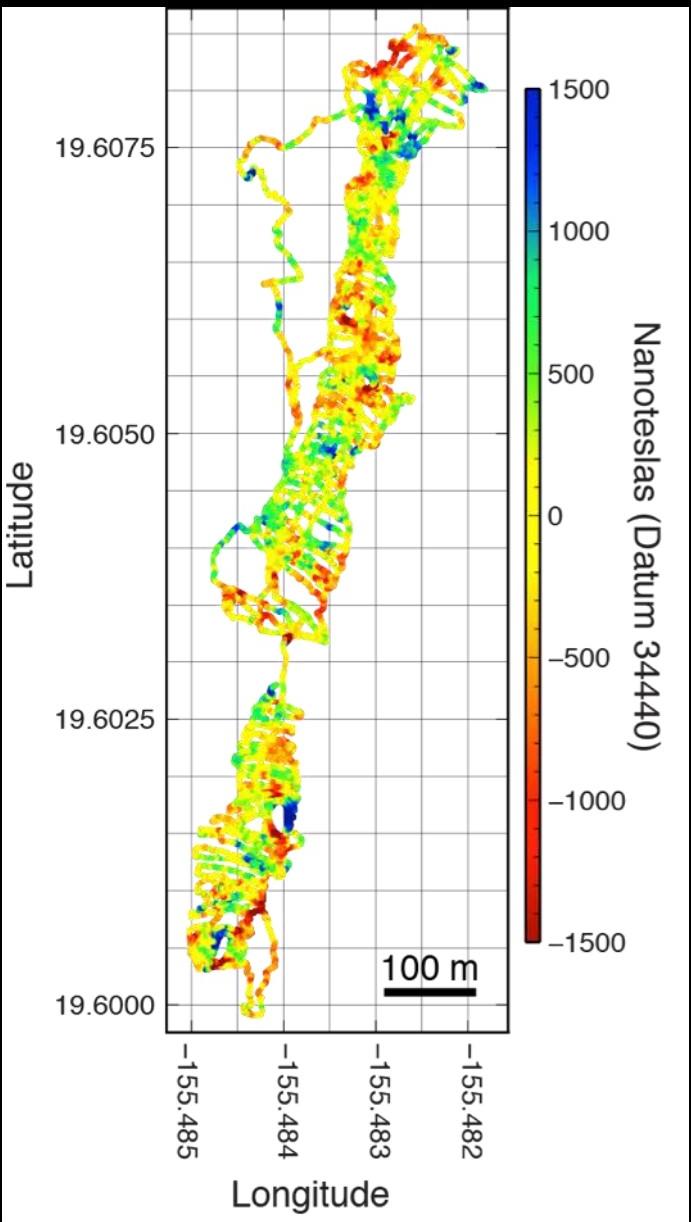
Preliminary studies of Lava Tubes

- Magnetometry
- LiDAR mapping
- Field X-ray Fluorescence (XRF) chemical analyses
- X-ray Diffraction (XRD) mineralogical analyses
- Evolved Gas Analysis Mass Spectrometry (EGA-MS) for constraints on mineralogy and chemistry
- Sequencing of DNA from collected samples to understand the microbial populations

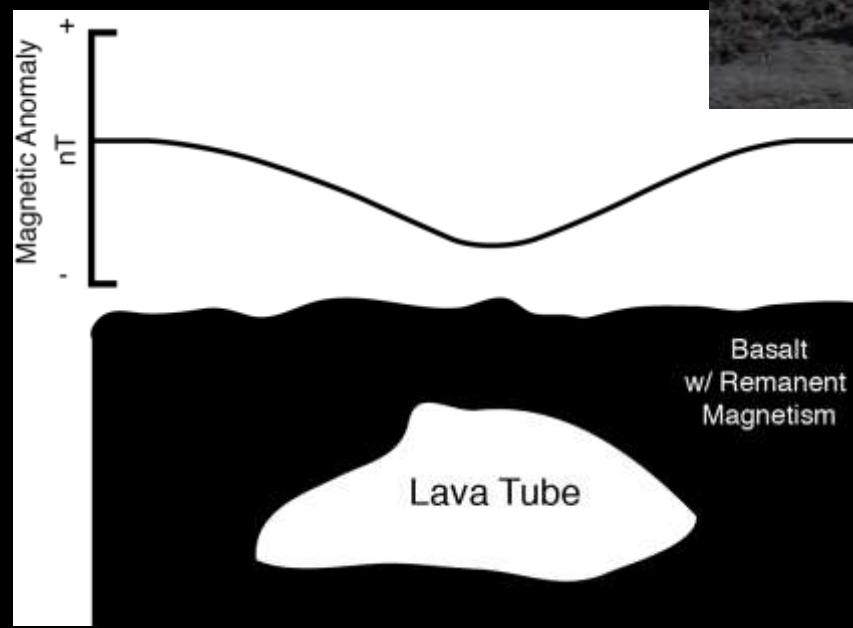


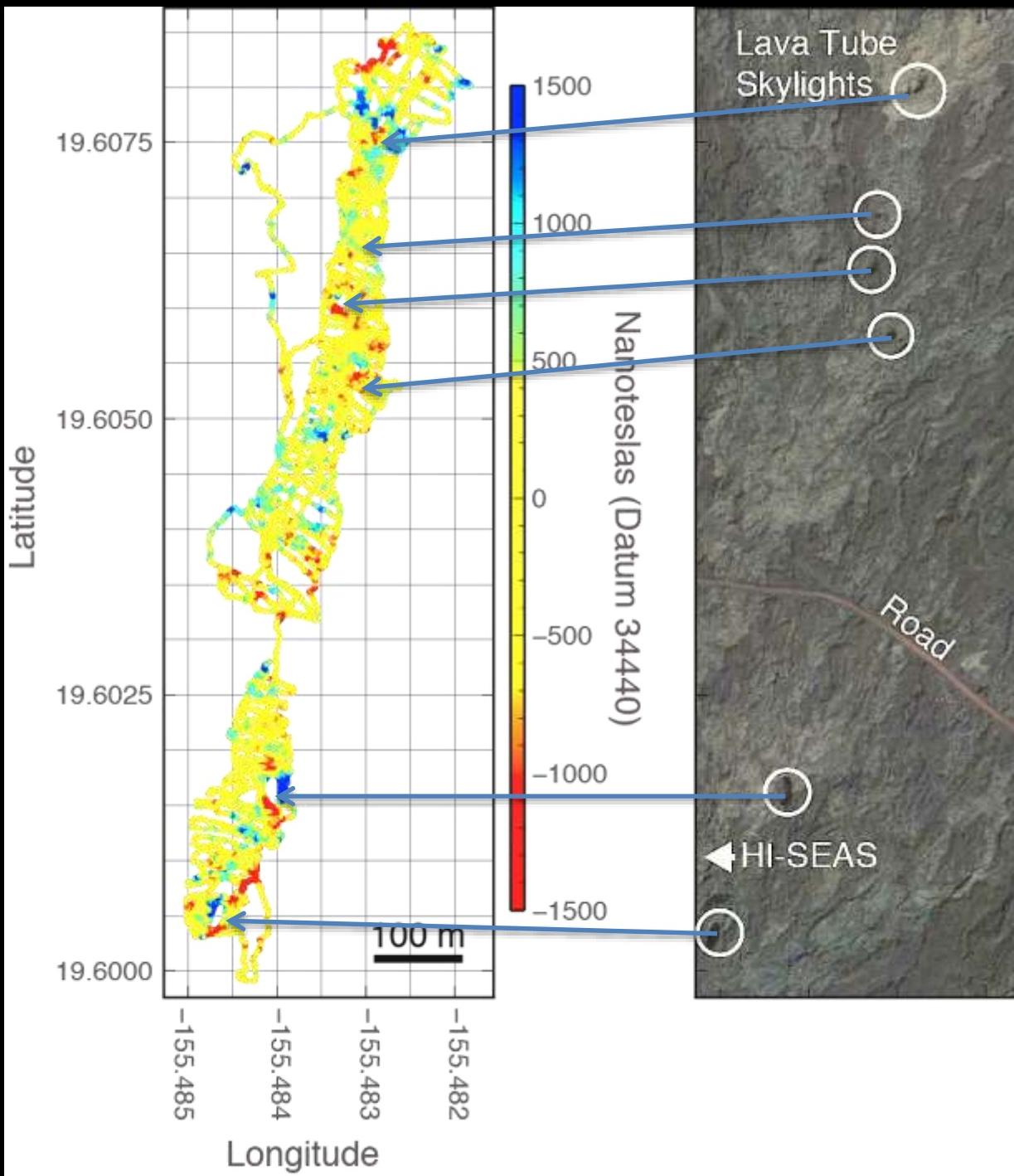
Magnetometry

Nick Schmerr, Brian Shiro



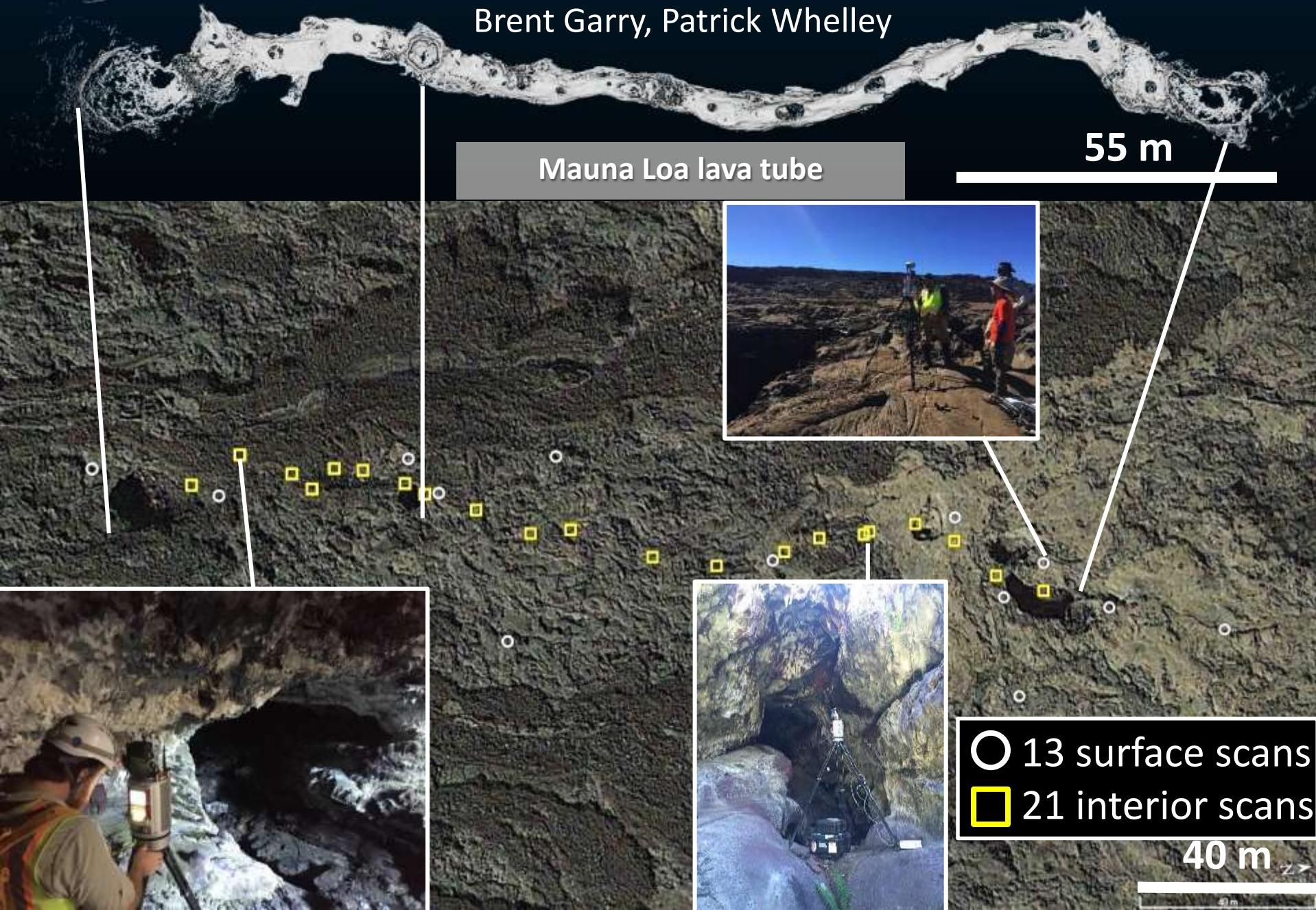
- Measured total magnetic field anomaly on lava flow with a GEM Systems Overhauser Magnetometer
- Search for subsurface cavities by looking for a deficit in local magnetic field strength



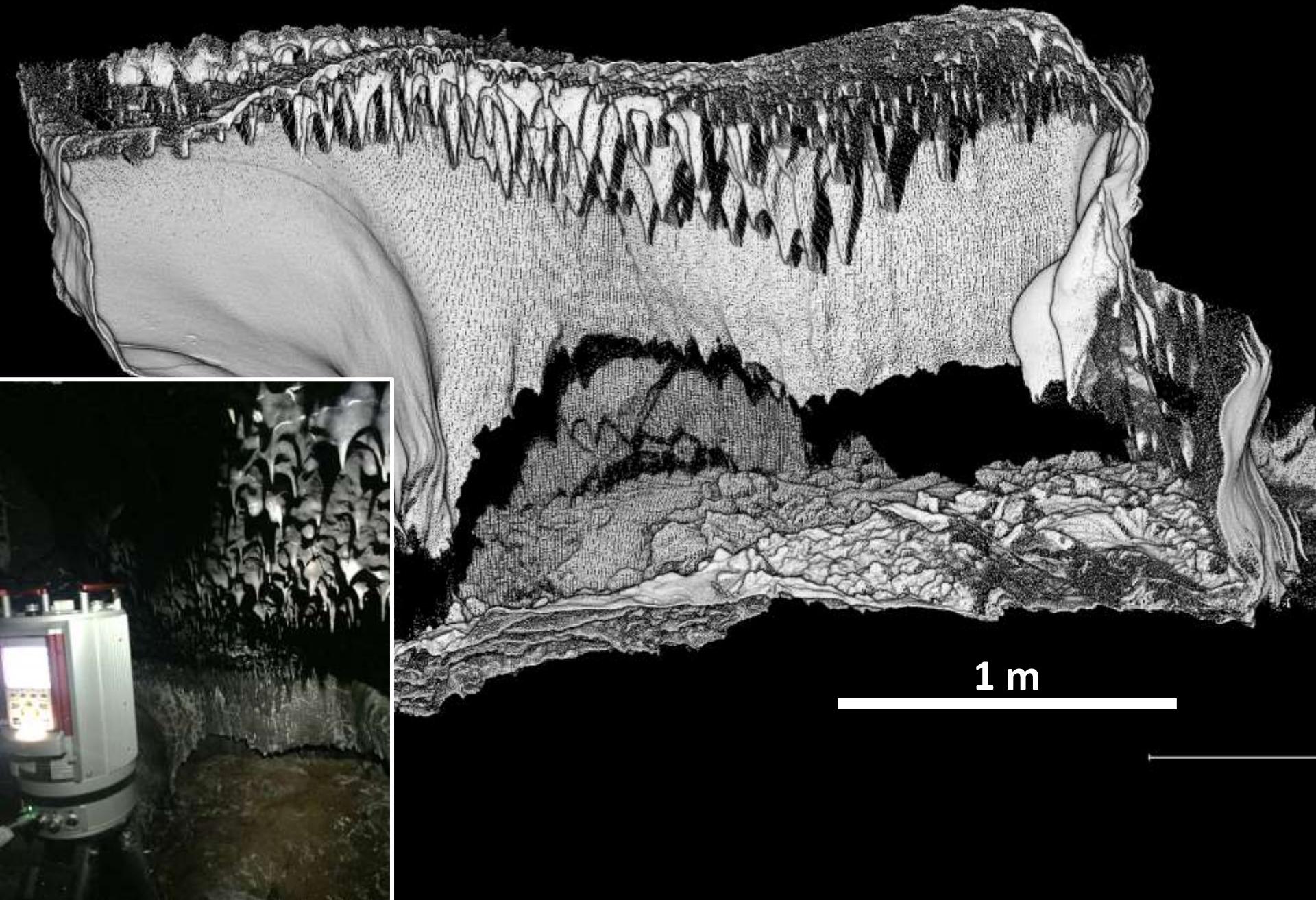


LiDAR

Brent Garry, Patrick Whelley



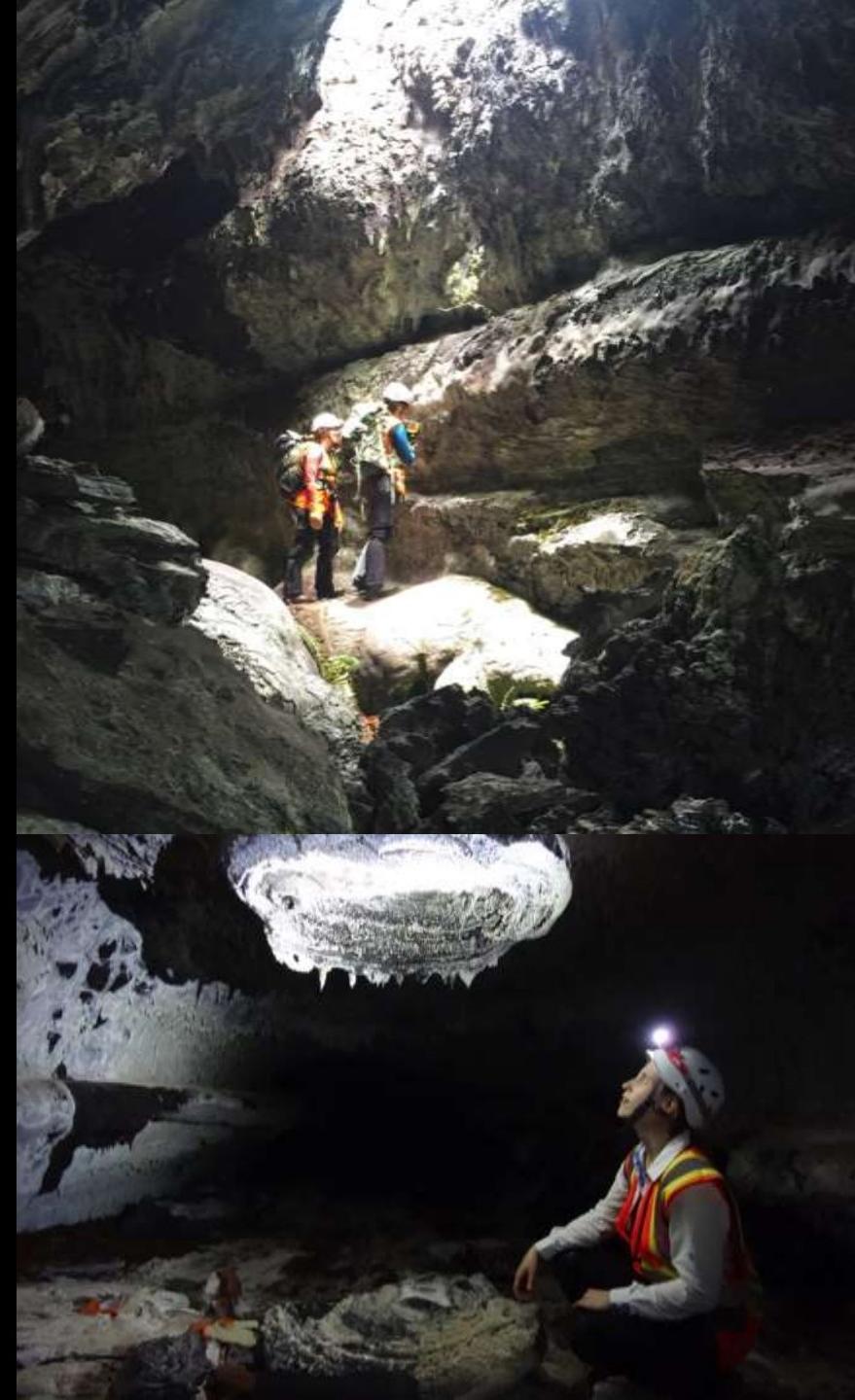
Lidar captures details of flow textures



XRF analyses

Kelsey Young, Debra Needham

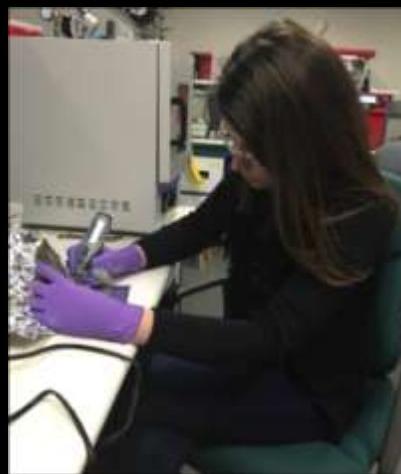
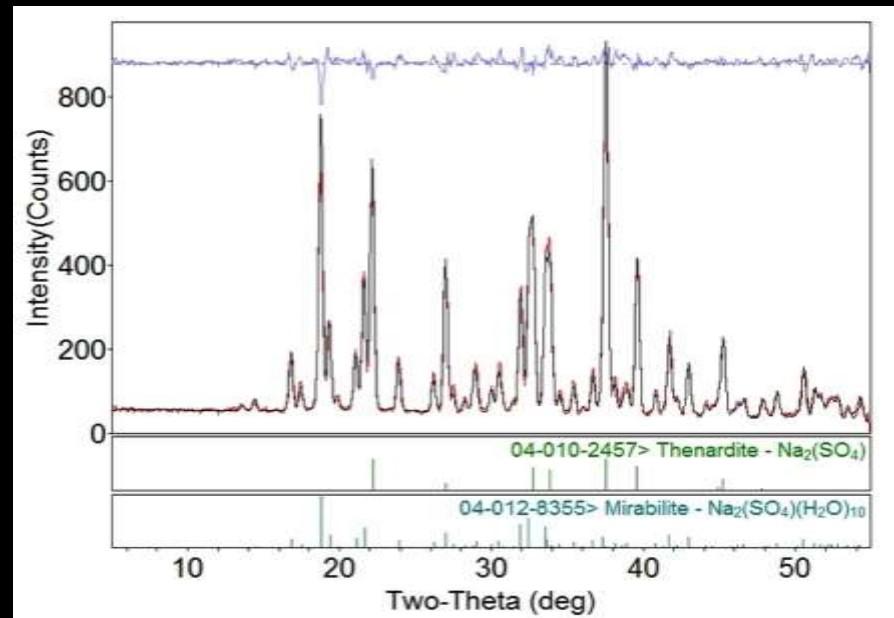
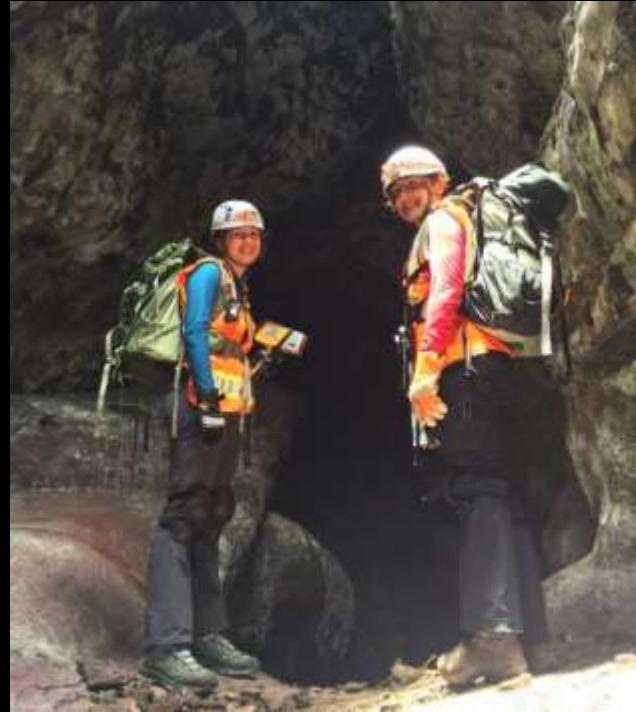
- Field analyses enabled in situ constraints on sample chemistry
 - e.g., white powdery deposits hypothesized to be Na sulfate based on field spectra dominated by Na and S
 - Confirmed by XRD analyses
- Spectra were collected from a large variety of cave features, data analysis still in progress



XRD analyses

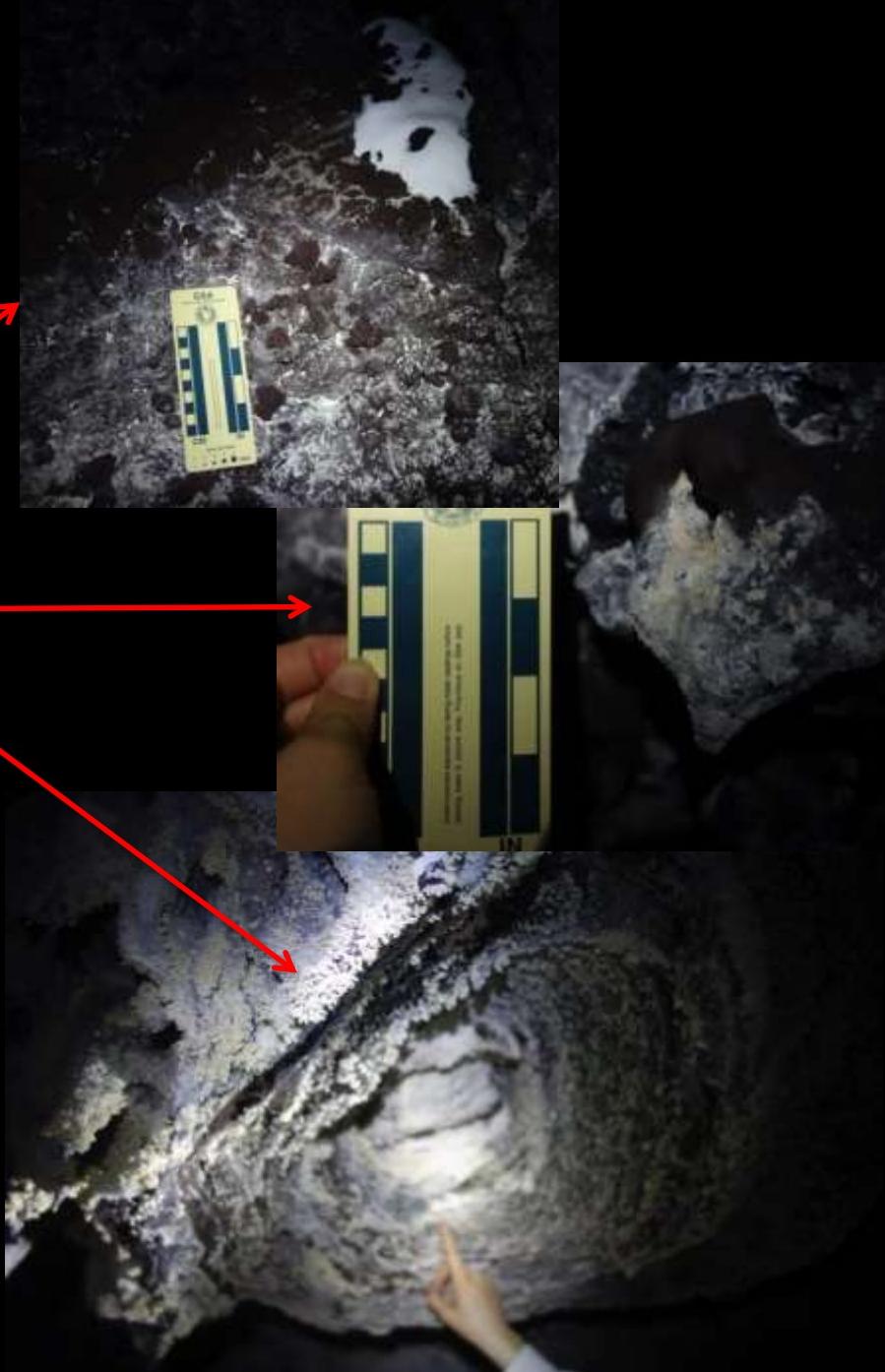
Amy McAdam, Slavka Andrejkovicova,
Christine Knudson

- Samples collected for EGA-MS and microbial analyses in the same areas
- Samples cleanly processed in the lab
- Analyzed on an Olympus Terra XRD instrument or Bruker D8 Discover diffractometer



XRD analyses

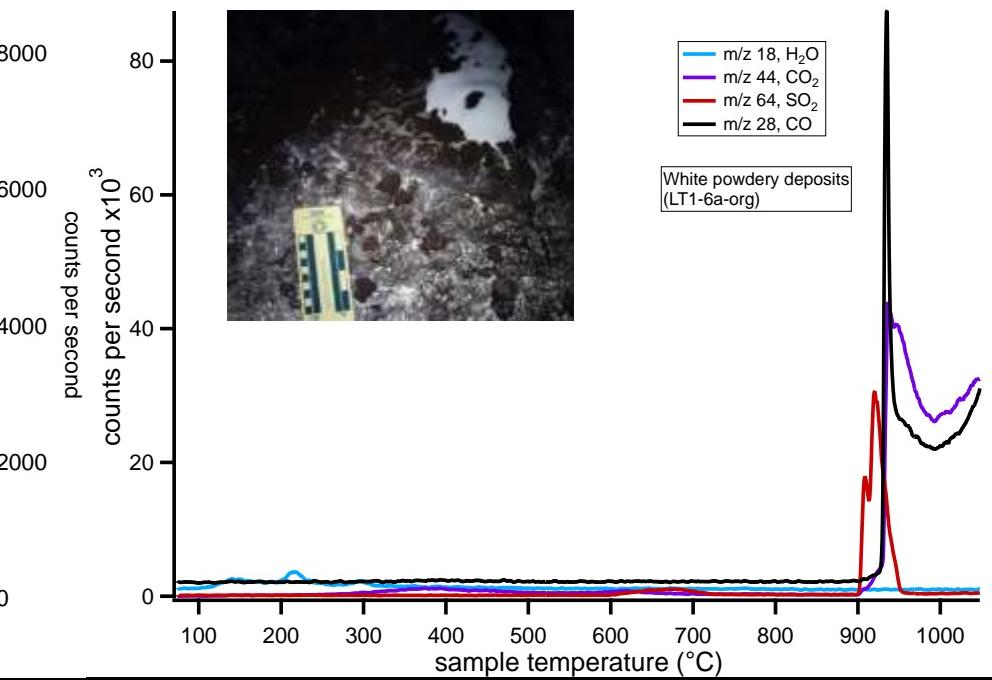
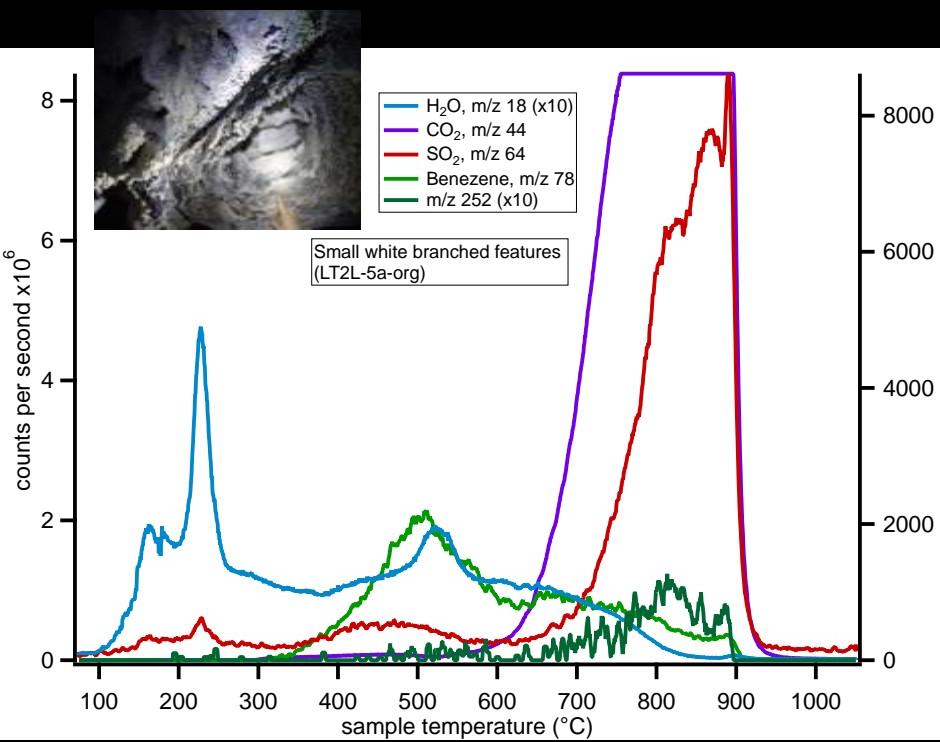
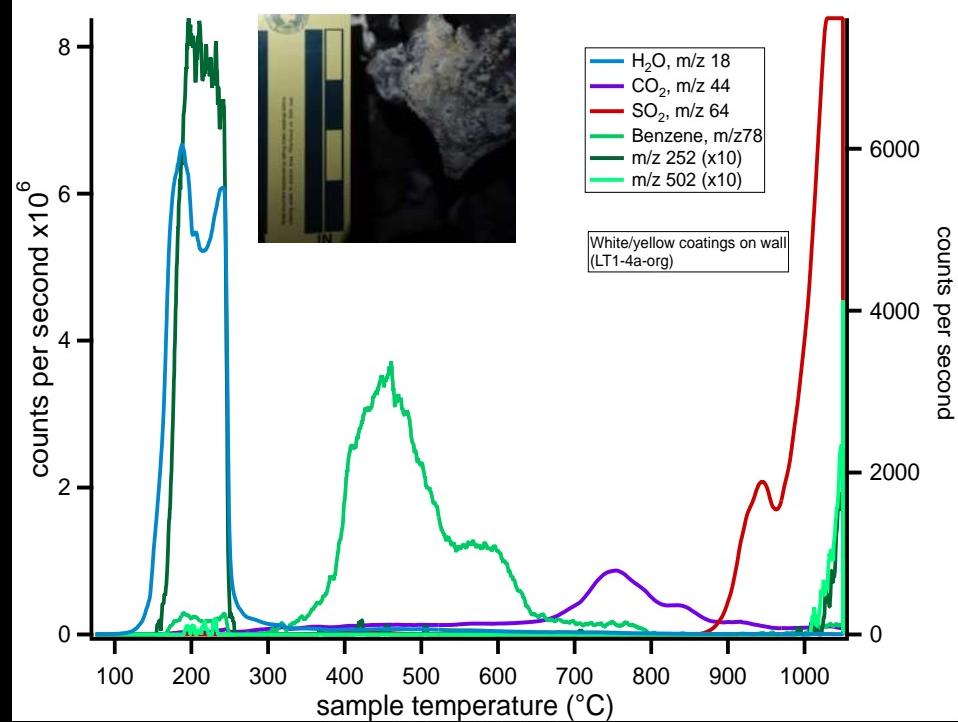
- Basalts contain minor pyrite
- White powdery deposits of Na sulfates
- White coatings of gypsum
- Small branched features: monohydrocalcite, calcite, and gypsum
 - Monohydrocalcite is metastable and forms from an Mg-bearing, amorphous Ca carbonate precursor (e.g., Rodriguez-Blanco et al., 2014)



EGA-MS analyses

Amy McAdam, Christine Knudson,
Slavka Andrejkovicova,

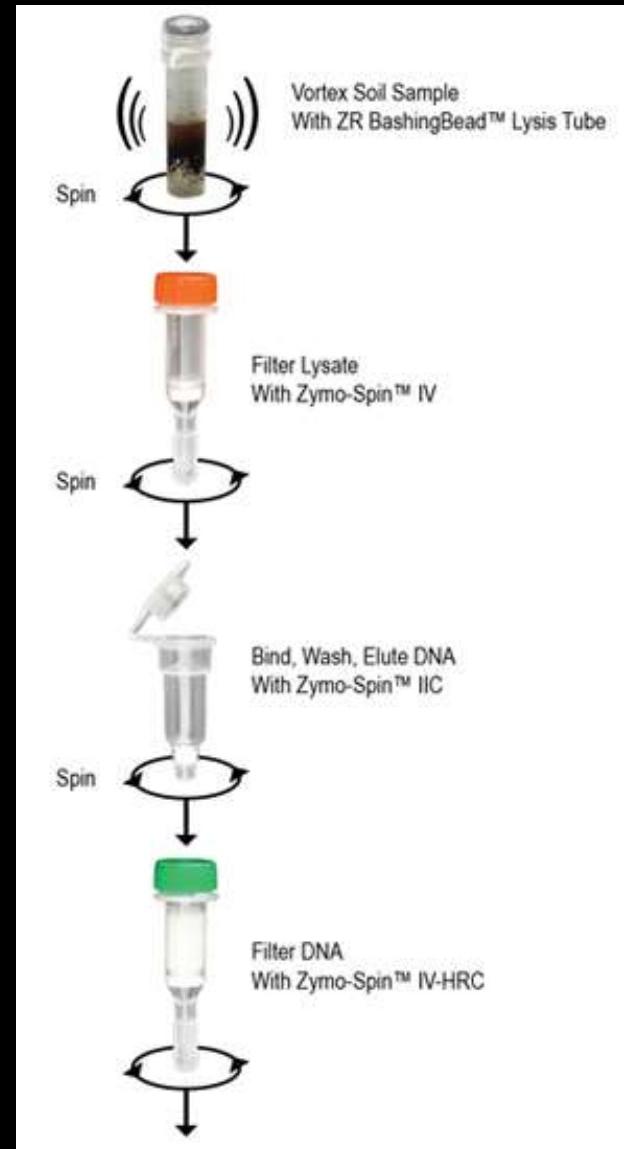
- Samples are heated; evolved volatiles are detected by a mass spectrometer
- Enables constraints on mineralogy, organic chemistry, and organic-mineral relationships



Preliminary DNA Sequencing

Sarah Stewart Johnson

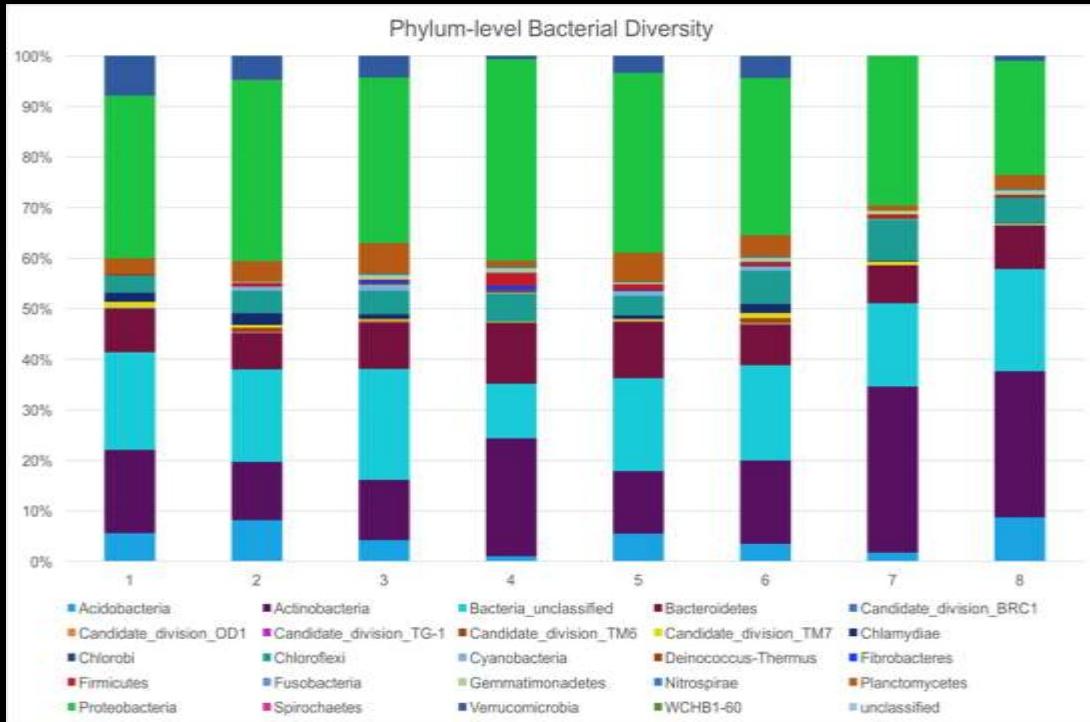
- Sample collection in Zymo DNA/RNA Shield Lysis Tubes in the field
- Homogenization followed by extraction with a Zymo Quick DNA kit
- Preliminary 16S sequencing on 8 samples from two lava tube areas (two replicates per sample)



Phylum-Level Bacterial Diversity

Sarah Stewart Johnson

- Broadly similar community profiles
- System dominated by bacteria by *Proteobacteria* and *Actinobacteria*
- Large proportion of unclassified bacteria (teal bars) and candidate divisions
- Deeper sequencing underway to elucidate metabolic pathways and novel organisms



Summary

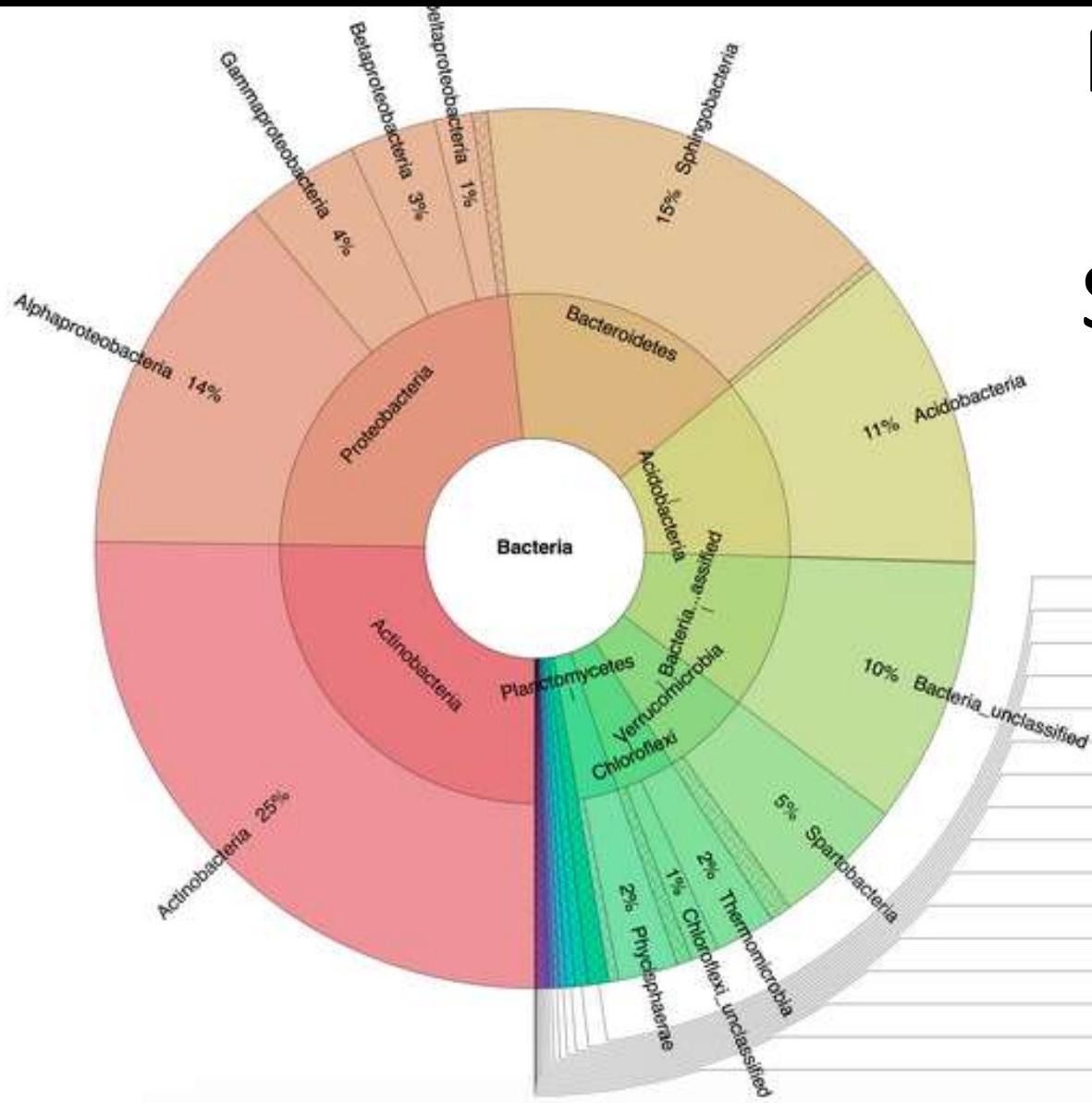
- Lava tubes in the martian subsurface could be detected by astronauts using magnetometry and mapped in detail with LiDAR
- Chemistry, mineralogy and microbiology data indicate that ongoing studies will help illuminate alteration characteristics and microbial associations within tube deposits, with implications for:
 - Habitability and astrobiology on Mars
 - Knowledge of minimum environmental conditions for sustaining life in young basaltic terrains
- Ongoing work will provide important information for HEOMD studies of potential human exploration or use of lava caves on Mars
- Caves are both a science target and a potential resource for manned missions
 - How do we minimize human contamination of sensitive locations?
 - How do we ensure safe subsurface spaces for humans?
 - What instruments are needed and what types of missions (robotic missions, telerobotics during manned missions)?

A photograph showing a dark, rocky landscape, possibly a cave entrance or a deep ravine. A bright, glowing opening is visible in the distance, illuminating the surrounding rock formations.

Thanks!

Preliminary DNA Sequencing

Sarah Stewart Johnson



Gemmatimonadetes	0.8%
Chlamydiae	0.5%
Nitrospirae	0.3%
Candidate_division_TM7	0.2%
Cyanobacteria	0.2%
Chlorobi	0.1%
Fibrobacteres	0.1%
Candidate_division_TM6	0.09%
Firmicutes	0.09%
Deinococcus-Thermus	0.08%
Candidate_division_BRC1	0.07%
WCHB1-60	0.05%
Candidate_division_OD1	0.02%
Spirochaetes	0.004%
Fusobacteria	0.004%
Candidate_division_TG-1	0.0007%

- Several interesting bacteria present
 - Candidate divisions, unclassified bacteria, deltaproteobacteria (can be sulfur oxidizers and reducers)
 - Next step: sequence down to the next level to get an idea of metabolisms